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(54) Storage arbiter for high resolution output systems

(57) A storage arbiter (10) for controlling storage device access across a network (N1) of raster image processors (14) (RIPs), output devices (16) and storage devices (20). The storage arbiter (10) coordinates the read/write requests from the RIPs (14) and output devices (16) to the storage devices (20). The storage arbiter (10) assigns a command priority level to each access request, with output devices (16) given a higher level

than RIPs (14). A request queue of pending access requests is maintained for each storage device (20). As new requests for access to a storage device (20) are received, they are added to the request queue for that storage device. When a storage device (20) becomes available, the oldest request with the highest priority level in the corresponding request queue is initiated.

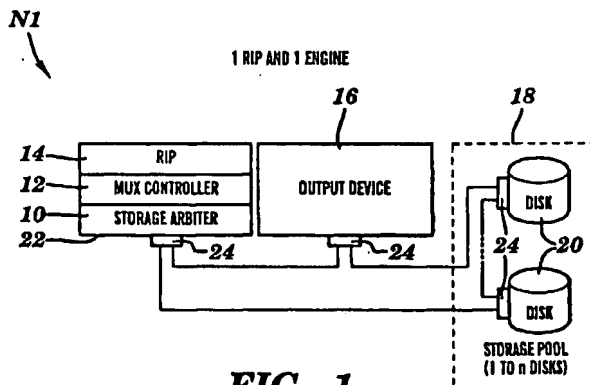


FIG. 1

Description

FIELD OF THE INVENTION

The present invention relates in general to high resolution output systems. More particularly, the present invention is directed to a method and apparatus for providing data buffering between at least one raster image processor (RIP) and at least one output device such as an imagesetter, platemaker, digital proofer, digital color printer, or the like, to maximize the data production and data consumption of each RIP and output device, respectively. Any application involving the production and consumption of large parcels of data may take advantage of the present invention.

BACKGROUND OF THE INVENTION

As known in the art of electronic prepress systems, output devices such as laser imagesetters require a steady stream of imaging data to operated efficiently. Unfortunately, the RIP(s) which provide the imaging data to an imagesetter generally operate in a bursty manner, commonly leaving the imagesetter starved for imaging data, or the RIP(s) waiting for the imagesetter to use previously supplied imaging data.

Several data buffering systems have been developed to allow an imagesetter and associated RIPs to operated more closely to their maximum data consumption and production rates, respectively. Typically, these data buffering systems use an arrangement of dedicated or shared storage buffers to temporarily store the imaging data rehired by the imagesetter. To operated efficiently, the storage buffers need to have a large storage capacity (multiple gigabytes) and fast storage access rates (megabytes/second).

There are many possible RAID solutions, but these tend to be cost prohibitive in cost/megabyte. A network of SSA disk drives could also be used to provide the needed storage capacity and access rates. Unfortunately, the level of storage device arbitration and command queue control available from SSA drives implementing a SCSI 2 protocol (SSA-S2P) is inadequate for complex applications with real time demands.

SUMMARY OF THE INVENTION

The present invention provides a storage arbiter for controlling storage device access across a network of RIPs, output devices and storage devices. The storage arbiter coordinates the read/write requests from the RIPs and output devices to the storage devices. This allows the storage devices to be shared by the RIPs and output devices, and accessed in a random, yet predictable, fashion.

The storage arbiter assigns a command priority level to each access request, with output devices given a higher level than RIPs. A request queue of pending

access requests is maintained for each storage device. As new requests for access to a storage device are received, they are added to the request queue for that storage device. When a storage device becomes available, the oldest request with the highest priority level in the corresponding request queue is initiated. This allows the output devices, which have real time penalties, to get higher priority when accessing the storage devices.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of the present invention will best be understood from a detailed description of the invention and preferred embodiments thereof selected for the purposes of illustration and shown in the accompanying drawings in which:

FIG. 1 illustrates a first network, including a single RIP, a single output device, and a storage pool, in which the storage arbiter of the present invention is used to track and coordinate access to the storage devices within the storage pool;

FIG. 2 illustrates a second network comprising two RIPs, a single output device, and a storage pool;

FIG. 3 illustrates a third network comprising a single RIP, a pair of output devices, and a pair of storage pools;

FIG. 4 illustrates a fourth network comprising four RIPs, a pair of output devices, and a pair of storage pools;

FIG. 5 is a flowchart illustrating the input processing logic flow of the present invention;

FIG. 6 is a flowchart illustrating the logic flow of the storage arbiter of the present invention; and

FIG. 7 is a flowchart illustrating the output processing logic flow of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The objects, features, and advantages of the present invention are illustrated in detail in the accompanying drawings, wherein like reference numerals refer to like elements throughout the drawings.

The storage arbiter, generally designated as 10, is preferably designed to be used in a network containing at least one RIP, at least one output device (e.g., an imagesetter), and at least one storage pool containing at least one storage device. In the following description, the components that control the data flow and storage/retrieval of data are referred to collectively as the MUX.

The network is used to convey control directives and requests between the nodes of the network and a MUX controller. Additionally, the network is used to convey output device control, status, and requests between RIPs and output devices, and page pixel data (e.g., image and/or video data) corresponding to a print job

from RIP to storage device and from storage device to output device.

Referring now specifically to FIG. 1, there is illustrated a first network N1 incorporating the storage arbiter 10 of the present invention. The network N1 includes a storage arbiter 10, a MUX controller 12, a single software RIP 14, a single output device 16, and a storage pool 18 containing at least one storage device 20. As shown, the storage arbiter 10, MUX controller 12, and RIP 14 run on a single workstation 22 connected to the network N1. Alternately, the MUX controller 12 can run on a stand-alone workstation attached to the network N1, or can run on a workstation serving as a MUX switching station on the network N1. The RIP 14 may also be a hardware RIP attached to a node of the network N1 separate from the workstation 22.

Suitable network interfaces 24 are used to connect the output device 16, storage devices 20 and workstation 22 (running the storage arbiter 10, MUX controller 12, and RIP 14) in a network configuration. If necessary, depending on hardware requirements and the like, appropriate converters (not shown) may be used to ensure data transfer compatibility between the components of the network. The MUX controller 12 manages the print jobs sent from the RIP 14 to the output device 16.

The MUX controller 12 is also responsible for memory allocation on the storage devices 20, and for associating that storage with a specific print job. The list of storage locations associated with a print job are provided to specific network nodes as needed by the MUX controller 12.

When the RIP 14 is available to start processing a print job for output on the output device 16, it sends the MUX controller a ready status signal. In response, the MUX controller 12 finds and reserves storage in a storage device 20 in the storage pool 18 associated with the output device 16. The RIP 14 is then given permission by the MUX controller 12 to start processing the print job, and the data produced by the RIP 14 is stored on a storage device 20 under control of the storage arbiter 10. When the output device 16 becomes available, the MUX controller 12 sends the data associated with the print job from the storage device 20 to the output device 16.

The RIP 14 and output device 16 may access multiple storage devices 20 in the storage pool 18. This allows the storage and retrieval rates of the network N1 to be limited by the network bandwidth (20-40 MB/s for SSA) rather than the lower data transfer rate to a single storage device 20 (2-7 MB/s).

When the RIP 14 or the output device 16 needs to access a storage device 20, it must first request permission from the storage arbiter 10. The storage arbiter 10 tracks the availability of each of the storage devices 20 in the storage pool 18, and only allows one RIP 14 or one output device 16 to access a particular storage device 20 at a time. The RIP 14 or output device 16 currently

given access to that storage device 16 must report back to the storage arbiter 10 when its read/write operation has been completed. When a particular storage device 20 requested by the RIP 14 or output device 16 is unavailable, the storage arbiter 10 places the access request on a request queue. It may be possible for the RIP 14 or output device 16 to have more than one access request outstanding at a time. When the particular storage device 20 becomes available, the storage arbiter 10 checks the request queue for any pending requests for that storage device 20.

In the present invention, the storage arbiter 10 gives the output device 16 priority over the RIP 14 when accessing the same storage device 20. To provide this priority, the storage arbiter 10 uses a priority scheme when accessing the request queue. In the event that there are multiple requests on the request queue, the storage arbiter 10 selects the request having the highest priority. In cases where multiple requests have the same priority, the first (i.e., oldest) request in the request queue having that priority will be selected by the storage arbiter 10.

The storage arbiter 10 of the present invention may be incorporated into a wide variety of network configurations, several examples of which are illustrated in FIGS. 2-5. Of course, many other network configurations are possible.

In FIG. 2, the network N2 includes a storage arbiter 10, a MUX controller 12, and a first RIP 14 running on a workstation 22. The network N2 further includes a second RIP 14' (software or hardware), a single output device 16, and a storage pool 18 containing at least one storage device 20. The storage arbiter 10 and MUX controller 12 coordinate the access requests from the RIPs 14, 14' and the output device 16, and the resultant data transfers from the RIPs 14, 14' to the storage devices 20 in the storage pool 18, and from the storage devices 20 to the output device 16.

A network N3 including a single RIP 14 and a pair of output devices 16, 16', is illustrated in FIG. 3. In this network each output device 16, 16' is associated with a corresponding storage pool 18, 18', respectively, each containing at least one storage device 20. The storage arbiter 10 and MUX controller 12 coordinate the access requests from the RIP 14 and the output devices 16, 16', and the resultant data transfers between the RIP 14, the storage devices 20 in the storage pools 18, 18', and the output devices 16, 16'.

A final example of a network N4 is provided in FIG. 4. In this network there are two zones A, B, each including a pair of RIPs 14, a single output device 18, and a storage pool 18 comprising at least one storage device 20.

The present invention provides a method and apparatus for maximizing the utilization of RIPs and output devices, wherein the RIPs and output devices are busy producing and consuming data, respectively, at high rates of speed. Each RIP stores the data it produces in a

storage pool associated with a particular output device. The output device retrieves that data from the storage pool during the data consumption process. In the case where the output device is an imagesetter, for example, each RIP generates pixel image data based on input page descriptions. The imagesetter consumes the data by imaging the pixel image data onto output media such as film or a printing plate.

Each storage pool typically includes a plurality of storage devices. The minimum number of storage devices is a function of the data consumption rate and the effective read/write data rate of each output device. Additional storage devices can be added to a storage pool to support more RIPs and/or provide longer term storage for the output data.

To keep an output device running at full speed, the minimum number of storage devices is equal to the output device data rate divided by the transfer rate of each storage device (assuming identical storage devices). To keep an output device running at full speed and to allow time for the RIPs to replenish the supply of image data, the minimum number of storage devices is equal to two times the output device data rate divided by the transfer rate of each storage device. Of course, the minimum number of storage devices may be reduced by using a suitable data compression technique.

During operation of the output system, the output device(s) and RIP(s) compete for read/write access of the storage devices. The storage arbiter 10 of the present invention regulates access to the storage devices. A description of the input processing, storage arbiter processing, and output processing provided by the present invention is described below. For simplicity, the processing flow of the present invention is described with regard to the network N1 illustrated in FIG. 1, wherein the storage pool 18 contains a single storage device 20. However, it should be readily apparent that the processing flow described herein below may be applied to any of the networks N2, N3, N4, as well as other suitable networks, without departing from the scope of the present invention.

Input Processing

To begin processing a print job, a PC, MAC or workstation (not shown) sends data in a page description format to a RIP 14. The RIP 14 notifies the MUX controller 12 of the existence of new print job (page dimensions and output resolution included). The MUX controller 12 determines the approximate amount of storage needed for the print job and reserves that storage in a storage device 20 in the storage pool 18. The MUX controller 12 sends the RIP 14 instructions to begin processing the print job, and provides the RIP 14 with the storage locations in the storage device 20 where the image data for the print job is to be stored. A flowchart 40 illustrating the input processing logic flow is provided in FIG. 5.

When a RIP 14 has a block of data to store, it consults 42 the list of storage locations provided by the MUX controller 12, requests access 44 to the appropriate storage device 20 from the storage arbiter 10, and awaits access permission 46. The storage arbiter 10 receives the request and places the request on a request queue for that storage device 20. When the storage device 20 becomes available, the RIP 14 is sent permission by the storage arbiter 10 to access the storage device 20. The storage device 20 is now considered to be unavailable to all other devices (e.g., RIPs, output devices).

When the RIP 14 receives access permission, it begins writing 48 the data to the specified locations in the storage device 20 previously allocated by the MUX controller 12. Upon completion 50 of the data storage, the RIP 14 notifies the storage arbiter 10 that it has finished the writing operation, thereby alerting 52, 54 the storage arbiter 10 that the storage device 20 is again available to other devices (RIPs and output devices) in the network. The storage arbiter 10 subsequently purges the access request for the just completed data storage from the request queue for storage device 20.

Should the storage allocated to the print job be inadequate, the RIP 14 requests additional storage by the MUX Controller 12. The RIP 14 then continues to produce and store the data in the additional storage location(s) in the storage device 20 specified by the MUX controller 12. When the print job has been completely stored in the storage device 20, the RIP 14 notifies the MUX controller 12 that the entire print job has been stored and how much storage was required. The MUX controller 12 frees any extra storage reserved for the print job and places the print job on the job list for the output device 16. The storage arbiter 10 subsequently marks the storage device 20 as available, and the next access request on the access queue is granted.

In the simple network N1 of FIG. 1, the next access request is most likely a (higher priority) read operation by the output device 16, where the data from the just processed print job is read out of the storage device 20 and processed by the output device 16. In more complex networks including a plurality of RIPs, output devices, and storage devices, the next access request that is granted for read/write access to a particular storage device is dependent upon the priority of the access request in the request queue for that storage device. As described above, the storage arbiter 10 uses a priority scheme when accessing the request queue for each storage device 20, wherein the highest (or oldest highest) request on the request queue for each storage device 20 is selected by the storage arbiter 10.

Storage Arbiter Processing

A flowchart 60 of the logic flow of the storage arbiter 10 is illustrated in FIG. 6. The storage arbiter 10 is responsible for tracking the availability of each storage device 20 in the network. It is typically inactive,

waiting 62 for an access request or a storage device available status message. The storage arbiter 10 parses 64 an incoming access request or a storage device available status message and performs different operations in response to the parsing result.

In response to a storage device available status message, the storage arbiter 10 marks 66 the storage device 20 as available, and checks 68 the request queue for any pending requests for access to the storage device 20. If there are no pending requests, the storage arbiter awaits 62 another access request or a storage device available status message. If there are pending requests on the request queue for the storage device 20, the storage arbiter 10 fetches 70 the highest priority request in the request queue, marks 72 the storage device 20 as unavailable, and sends 74 an access permission message to the originator of the access request. The storage arbiter 10 then awaits 62 another access request or a storage device available status message.

Upon receipt of a new access request, the storage arbiter 10 initially processes the access request by checking 76 the availability of the requested storage device 20. If the storage device 20 is available, the storage arbiter 10 marks 72 the storage device 20 as available, and sends 74 an access permission message to the originator of the access request. If the requested storage device 20 is unavailable, the access request will be placed 78 on a request queue associated with the storage device 20. The storage arbiter 10 then awaits 62 another access request or a storage device available status message.

Output Processing

A flowchart 80 illustrating the output processing logic flow is provided in FIG. 7. When an output device 16 is available and there are print jobs for it to run, the MUX controller 12 starts a new print job at the output device 16. The MUX controller 12 sends the list of storage locations in the storage device 20 that hold the image data corresponding to the print job to the output device 16.

When the output device 16 requires a block of data for the print job, it attempts to access 82 a storage location in the list of storage locations corresponding to that print job by sending 84 an access request to the storage arbiter 10. The storage arbiter 10 receives the access request and places it on the request queue for that storage device 20. The output device 16 remains idle until it receives 86 permission from the storage arbiter 10 to access the storage device 20. When the storage device 20 becomes available, the storage arbiter 10 sends access permission to the output device 16. At this point, the storage device 20 is unavailable to all other devices (e.g., RIPs, output devices) on the network.

After receiving access permission from the storage arbiter 10, the output device 16 reads 88 a data

block from the storage device 20. When the data block has been completely read 90, the output device 16 notifies 92, 94 the storage arbiter 10 that the transfer has been completed, and that the storage device 20 is once again available. When the output device 16 finishes outputting the data block, it is ready to access 96 the next data block in the print job.

When the output device 16 completes the print job, it notifies the MUX controller 12 that the print job has been processed. The output device 16 is now considered to be available, and any storage locations in the storage device 20 associated with the finished print job can be reused to store data corresponding to new print jobs from the RIPs.

The foregoing description of the present invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and many modifications and variations are possible in light of the above teaching. Such modifications and variations that may be apparent to a person skilled in the art are intended to be included within the scope of this invention as defined by the accompanying claims.

Claims

1. A method for providing data buffering between at least one raster image processor (RIP) (14), a storage pool (18) including at least one storage device (20), and at least one output device (16), comprising the steps of:

receiving an access request from one of said RIPs (14) or one of said output devices (16) to access one of the storage devices (20) in said storage pool (18);

storing each access request (78) for a specific storage device (20) in a request queue for that storage device;

assigning a first command priority level to said access request if said access request is received from one of said RIPs (14);

assigning a second, higher priority level to said access request if said access request is received from one of said output devices (16);

determining (76) if any of said storage devices (20) becomes available; and

if a storage device (20) is available, granting the oldest access request with the highest command priority level in the request queue for the available storage device, thereby allowing the RIP (14) or output device (16) having the oldest, highest priority access request to access the available storage device.

2. The method according to claim 1, further including the input processing steps of:

- sending a print job to one of said RIPs (14) (RIP A);
determining a storage requirement for data corresponding to said print job; reserving storage in at least one of said storage devices (20) (STORAGE A) for said print job data; providing RIP A (14) with storage locations in STORAGE A (20) for the storage of said print job data; and
instructing RIP A (14) to begin processing said print job to produce said print job data.
3. The method according to claim 2, wherein said input processing steps further include the steps of:
- determining when RIP A (14) has at least a portion of said print job data available for storage;
outputting an access request for permission to access STORAGE A (20) for the storage of the print job data produced by RIP A (14);
storing the access request for STORAGE A (20) on the request queue for STORAGE A.
4. The method according to claim 3, wherein said input processing steps further include the steps of:
- determining when STORAGE A (20) becomes available;
if STORAGE A (20) is available, determining the command priority level of the access request for permission to access STORAGE A for the storage of the print job data produced by RIP A (14); and
if STORAGE A (20) is not available, denying access for RIP A (14) to store said print job data on STORAGE A.
5. The method according to claim 4, wherein said input processing steps further include the steps of:
- allowing RIP A (14) to store said print job data on STORAGE A (20) if STORAGE A is available and if the access request for permission to access STORAGE A for the storage of the print job data produced by RIP A is the oldest access request with the highest command priority level in the request queue for STORAGE A; and
denying access for RIP A (14) to store said print job data on STORAGE A (20) if the access request for permission to access STORAGE A for the storage of the print job data produced by RIP A is not the oldest access request with the highest command priority level in the request queue for STORAGE A.
6. The method according to claim 5, wherein said input processing steps further include the steps of:
- marking STORAGE A (20) as unavailable during the storage of said print job data therein; and
marking STORAGE A as available (52) upon completion of the storage of said print job data.
7. The method according to claim 1, further including the output processing steps of:
- initiating a print job on one of said output devices (16) (DEVICE A);
determining storage locations in at least one of said storage devices (20) (STORAGE A) containing print job data corresponding to said print job;
providing DEVICE A (16) with storage locations in STORAGE A (20) containing said print job data; and
instructing DEVICE A (16) to begin outputting said print job.
8. The method according to claim 7, wherein said output processing steps further include the steps of:
- outputting an access request (84) for permission to access the print job data stored on STORAGE A (20).
storing the access request for STORAGE A (20) on the request queue for STORAGE A.
9. The method according to claim 8, wherein said output processing steps further include the steps of:
- determining when STORAGE A (20) becomes available;
if STORAGE A (20) is available, determining the command priority level of the access request for permission to access the print job data stored on STORAGE A; and
if STORAGE A (20) is not available, denying DEVICE A (16) access to STORAGE A.
10. The method according to claim 9, wherein said output processing steps further include the steps of:
- allowing DEVICE A (16) to access the print job data stored on STORAGE A (20) if STORAGE A is available and if the access request by DEVICE A for permission to access the print job data on STORAGE A is the oldest access request with the highest command priority level in the request queue for STORAGE A; and
denying DEVICE A (16) access to STORAGE A (20) if the access request for permission to access the print job data on STORAGE A is not the oldest access request with the highest command priority level in the request queue for STORAGE A.

mand priority level in the request queue for
STORAGE A.

11. The method according to claim 10, wherein said
outputprocessing steps further include the steps of: 5

marking STORAGE A (20) as unavailable while
DEVICE A (16) isaccessing the print job data
stored therein; and

marking STORAGE A (20) as available (92) 10
upon completion of theaccessing of said print
job data.

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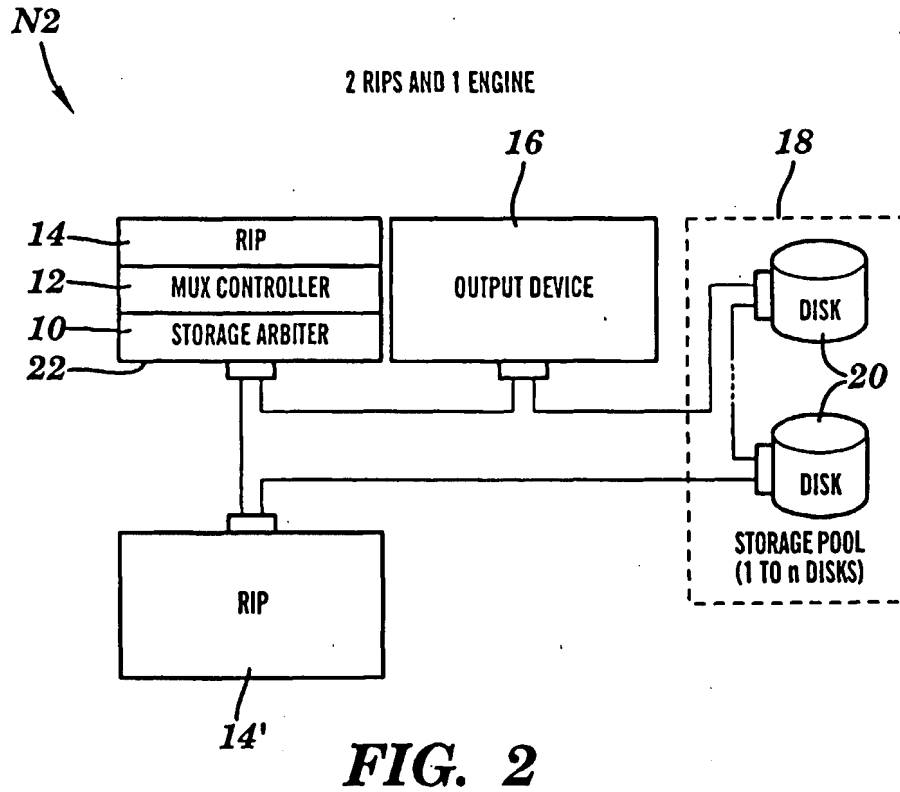
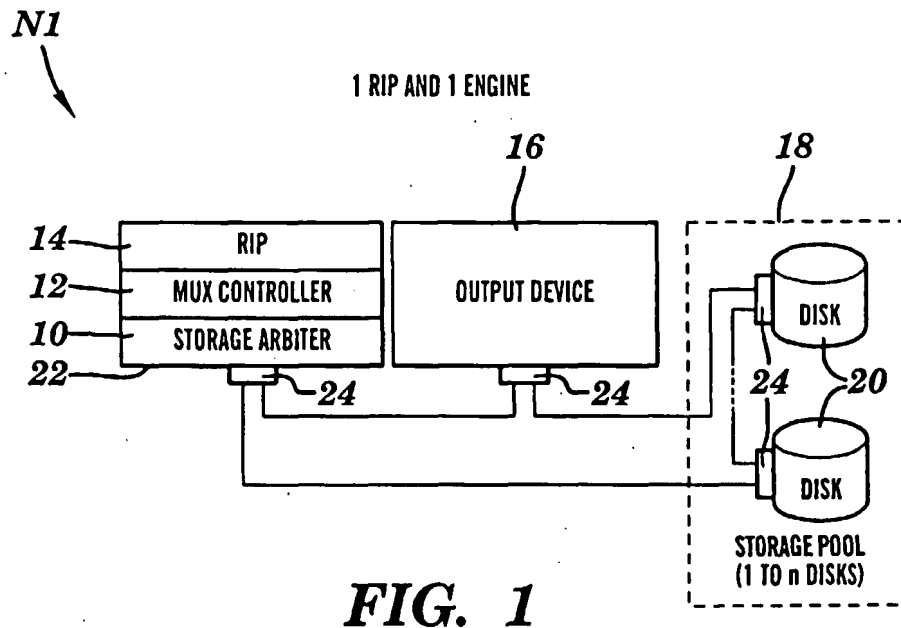
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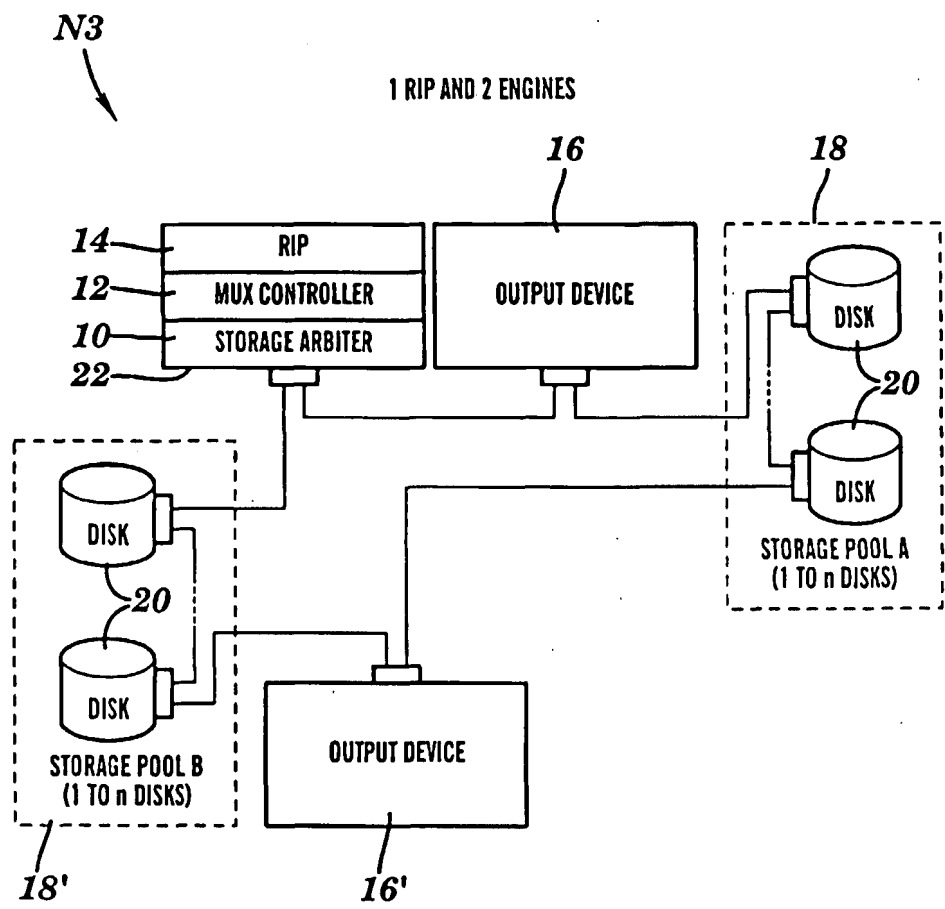


FIG. 3

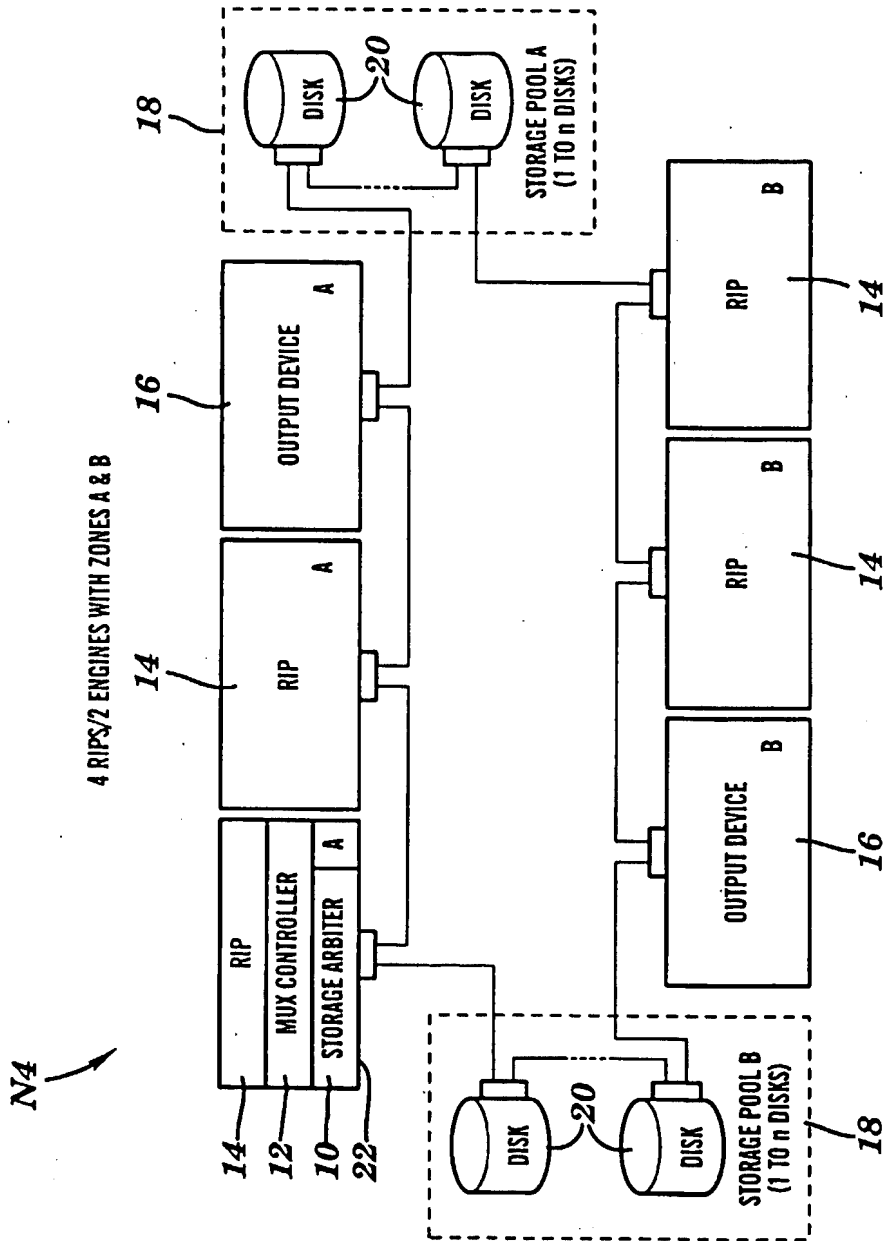
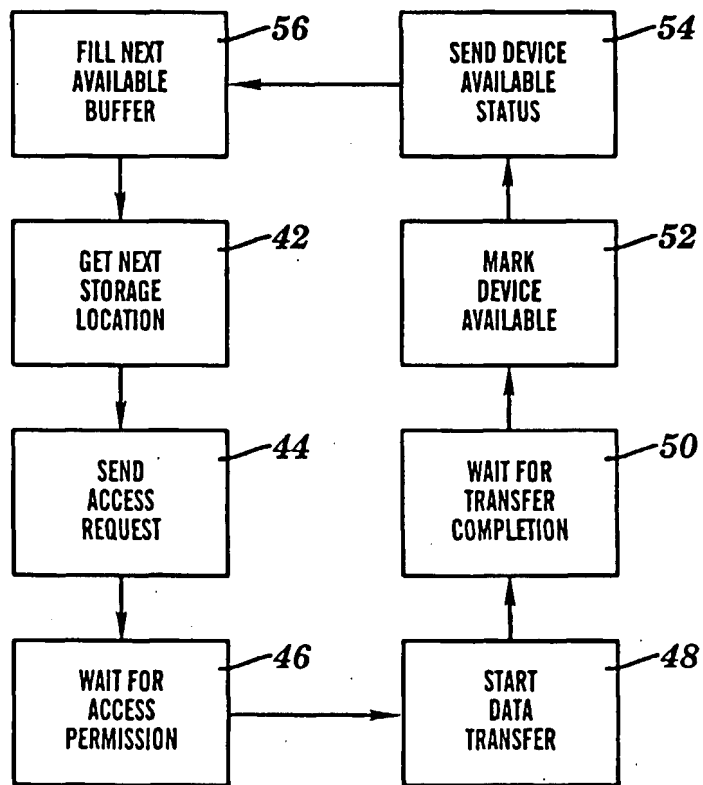
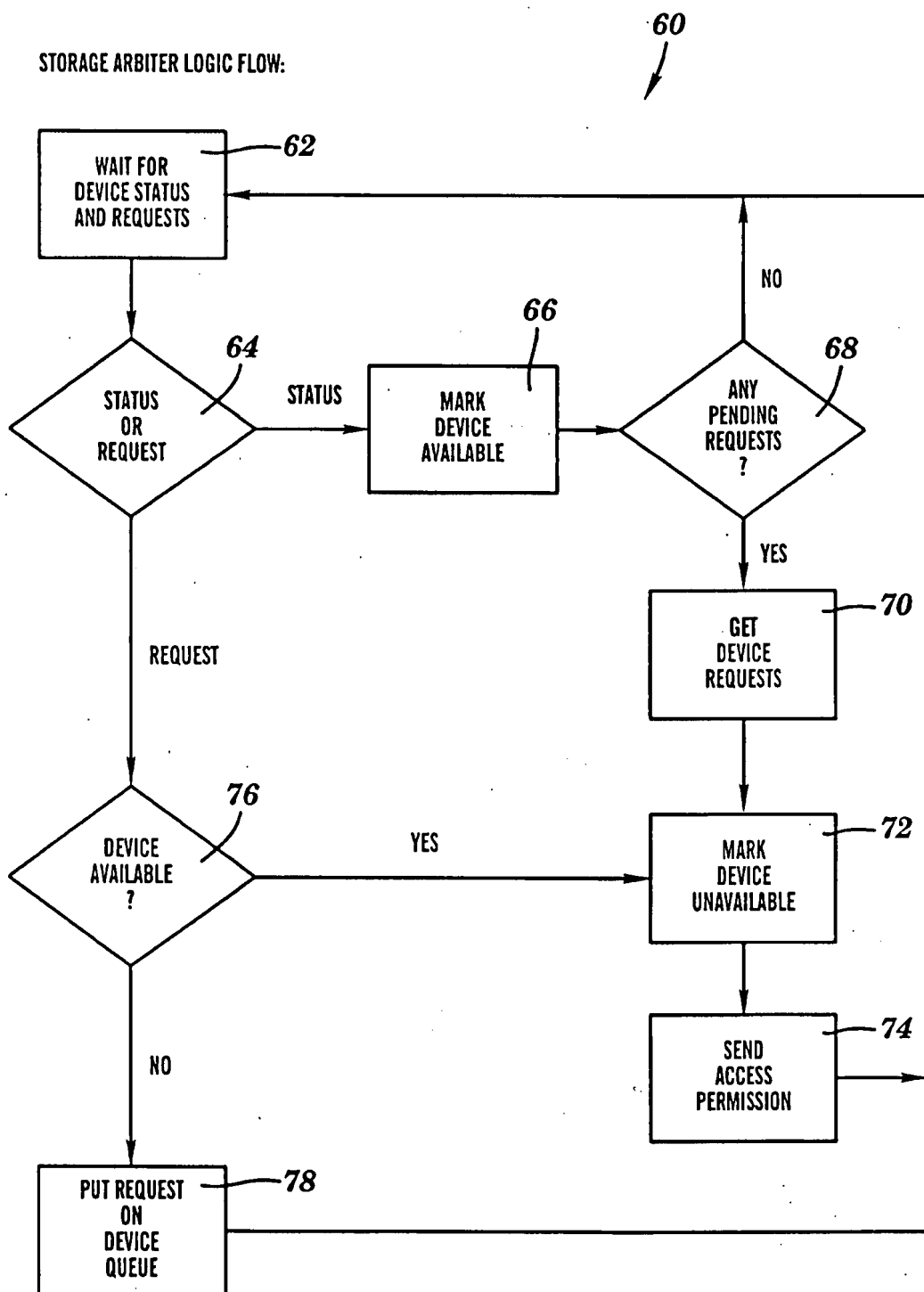


FIG. 4

INPUT LOGIC FLOW:

**FIG. 5**

**FIG. 6**

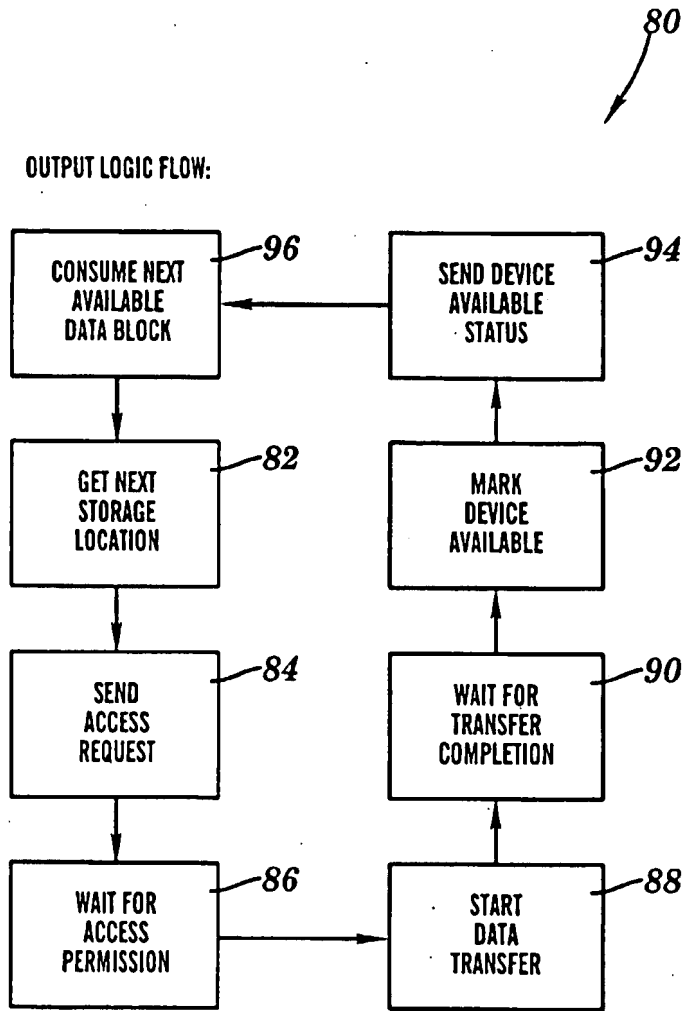


FIG. 7